INVESTIGATION OF ULTRA FINE STEATITE POWDER BASED ALKALI-ACTIVATED CONCRETE

A SYNOPSIS

Submitted by

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(Reg. No.201505226)

in partial fulfilment for the award of the degree

of

DOCTOR OF PHILOSOPHY

DEPARTMENT OF CIVIL ENGINEERING

SCHOOL OF MECHANICAL, AERO, AUTO AND CIVIL ENGINEERING

KALASALINGAM ACADEMY OF RESEARCH AND EDUCATION

(DEEMED TO BE UNIVERSITY)

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TAMIL NADU, INDIA

SEPTEMBER 2022

1. INTRODUCTION

The formation of geopolymers, which are X-ray amorphous aluminosilicate gels, is brought about by the alkali activation of the aluminosilicates present in the parent material. These gels, which can be used to connect aggregates such as sand or natural rocks, can be utilised in producing mortars and concrete. To put it more simply, geopolymers are inorganic binders that operate in a manner that is analogous to that of the more well-known Portland cement. Davidovits discovered the structure of geopolymer gel has a structural similarity with zeolite and gave the rock-like substance that was created the term "Geopolymers" artificially.

The process of industrialization results in the production of unwanted toxins, which are then released into the environment. It is vital to select an engineering process that will harm the environment as little as possible to keep up with the expanding rate of industrialization. This is the only way to keep up with the competition. On the other hand, the building industry is trending more and more toward using eco-friendly materials to satisfy the desire for a sustainable component in contemporary infrastructures. This is to meet the requirements of modern infrastructures. Concerns have been raised over the past 20 years due to the expansion of this concept and the escalation of global warming due to the extensive use of Portland cement and the high carbon dioxide levels linked with its manufacture. This is due to the fact that the production of Portland cement produces high levels of carbon dioxide.

A growing worry about the impacts of rubbish disposal on the environment has also inspired an increasing interest in identifying alternative channels for use. Because the requirements for construction materials are so intricate and stringent, no material can completely fulfil all the expectations set for them. As a consequence, an age-old concept that involves fusing multiple viable materials to satisfy a wide range of customer requirements is gaining popularity once more. Scientists who have worked in cement and concrete research until this point has identified and shown a great deal of interest in some of the unique properties of the alkali-activated cementitious material, such as high early strength growth and exceptional resistance to chemical attacks. But now, scientists who have worked in these fields have discovered something even more interesting.

For millennia, India has utilised soapstone as a carving tool. Because soapstone resists heat and is still visible when heated, welders and fabricators use it as a marker. Because its marks are readable and not permanent, it has also been used for many years as a marking tool by seamstresses, carpenters, and other artisans. Moulds for casting items made of soft metals, such as pewter or silver, can be made from soapstone. The soft stone is simple to carve and does not lose quality when heated. The finished item can be removed without difficulty thanks to soapstone's slippery surface. Alcoholic beverages can be chilled without diluting by using soapstones in place of ice cubes after being placed in the freezer. They are referred to as whiskey stones. Cheap biaxial porcelains with the nominal composition $(MgO)_3(SiO_2)_4$ are steatite ceramics. Steatite is roughly 67% silica and 33% magnesium by mass, with trace amounts of other oxides like CaO or Al_2O_3 also present. Because of its dielectric and thermal insulating qualities, steatite is utilised in various products, including tiling, substrates, washers, bushings, beads, and pigments.

2. LITERATURE REVIEW

Steatite, a soft and fine substance, should be adequately understood before being used in any construction material system because the product should be solid and durable. A literature review is needed to know how steatite can be used in alkali-activated systems. The literature review has four main categories.

1. Alkali activated concrete (AAC)

2. Sodium hydroxide and silicate influence binding property of AAC

3. Magnesium-based alkali activation/binding system and Steatite's uses

After the holistic review, the study's aim, scope, objective, and research methods are finalized.

Chen et al. [1] studied the alkali activation's effects on slag based lightweight aggregate concrete (AAS-LWAC They used two types of lightweight aggregate, clay ceramsite and shale ceramsite, and observed that the compressive strength of AAS-LWAC with fly ash ceramsite was found to be the greatest. Li et al. [2] compared the mechanical characteristics and autogenous shrinkage of alkali-activated materials-based concrete (AC) and ordinary Portland cement-based concrete (OC) as a function of curing age and degree of reaction. They noticed that the AC's tensile-to-

compressive-strength ratio is lower than OC's. and also modelled the mechanical properties of both OC and AC using a power law that is plotted against the degree of reaction. The author stated that AC displays higher autogenous shrinkage than OC, but it cracks at a later stage. Nevertheless, the degrees of reactivity at which AC and OC fractured are highly comparable. Autogenous shrinkage, elastic modulus, and self-induced stress are needed to compute concrete's elastic and creep deformations. AC is far creepier than OC.

Ahmad et al. [3] studied alkali-activated concrete using locally available metakaolin (MK) and limestone powder (LSP). OPC was used as a secondary binder. Each specimen had a different primary binder (MK or LSP), content (70%, 85%, or 100%), activator type (NaOH- or KOH-based), and sodium silicate/hydroxide ratio (1, 2.5, or 4). ANOVA and response surface methods were used for statistical investigation of the components' effects on strength (RSM). Their experiments showed that every component considerably affected the examined qualities, with the primary binder content having a greater impact than the alkaline composition. Two mixtures, 70% MK with sodium silicate/KOH ratios of 2.5 and 70% LSP with sodium silicate/KOH ratios of 4.0, had strengths over 20 MPa and could be used as structural concrete. Other mixtures were less than 20 MPa. Non-structural uses include backfill, footpath slab, and regulated low strength materials. Mehta et al. [4] used the Taguchi method to determine optimal values for a number of parameters, including the ratio of alkali solution to fly ash, sodium silicate to sodium hydroxide, fine aggregates to total aggregates, sodium hydroxide concentration, total aggregate content, and curing temperatures. Compressive strength, sorptivity, chloride permeability, and microstructural characteristics of GGBS-based alkali-activated concrete are also examined. They found calcium-based hydration products CSH and CASH and polymerization products NASH. The mixture compacted the alkali-activated binder matrix, reducing fractures and pores. Increasing GGBS from 0 to 20% in heat-cured fly ash-based alkali-activated concrete increases compressive strength by 52% and reduces sorptivity and chloride ion penetration by 35% and 78%, respectively. Alkalinizing fly ash formed this concrete.

Mengasini et al. [5] examined steatite's economic, environmental, and application issues. Global warming will cause sea levels to rise, necessitating coastal defences to protect coastal people. As greenhouse gas emissions increase, the need for

types of cement other than Portland cement will rise (OPC). Alkali-activated cements may offer feasible options and contain industrial waste. This research provides a laboratory analysis of concrete mixes based on GGBFS. The alkali-activator mixtures in this article include paper sludge ash (PSA). They considered combining and curing with seawater. Researchers evaluated the compressive strength of alkali-activated mixtures in maritime conditions to OPC systems. Adding paper sludge ash to alkali-activated slag concretes increased early strengths and decreased water absorption. Incorporating paper sludge ash increased cements' resilience to chloride and sulphate attacks in freshwater and seawater mixes. In alkali-activated systems, seawater increases sulphate resistance and compressive strength, whereas mixing and curing in seawater has negative consequences on OPC concretes. In alkali-activated systems, seawater boosted both features. Alkali-activated concrete mixtures can be used in marine environments.

Ibrahim et al. [6] said there hasn't been a study evaluating the performance of such concrete under acid attack. A key issue is the lack of data on optimal reaction parameter settings. In this study, NPs combined with 0 to 7.5% nano-silica ($nSiO_2$) were used to make ACC. ACC was cured at room temperature before sulfuric acid treatment ($H2SO_4aq$). Visual examination, microstructure, weight loss, and compressive strength loss were used to evaluate an NP/$nSiO_2$-based ACC after a year in an acidic environment. ANN and RSM models were constructed to forecast and optimize $nSiO_2$ to minimise weight and strength loss. Hypothesized and observed results show that increasing $nSiO_2$ improves microstructure. Microanalysis demonstrated Al, Ca, and Na leaching from binder structures. This leaching created extremely expansive compounds like gypsum, which produced cracking and disintegration in OPC and NP-based AAB with less $nSiO_2$. In modified AAC with 1% to 7.5% $nSiO_2$, weight loss and strength increased by 23%–39%. Control AAC- and OPC-based concrete lost over 50% of its weight and strength. Both were true [6]. Several countries are researching alkali-activated slag concrete as a possible alternative to Portland cement. Using powdered granulated blast furnace slag and sodium silicate solution as a binder, a high-strength alkali-activated Portland-cement-free concrete could be created. The study concrete lacks Portland cement. The Institute for Technological Research and the Polytechnic School of the University of Sao Paulo (IPT/EPUSP) created a mix design procedure for making concrete.

Compressive strength and elastic modulus were tested at 1, 3, 7, and 28 days. After 28 days, splitting tensile strength and static elasticity were tested. HSAASC exhibited significant compressive strength at the beginning and end of the process. At one day, the concretes' compressive strength ranged from 41 to 58 MPa, and at 28 days, 86 to 105 MPa. The IPT/EPUSP mix design strategy can be used to manufacture HSAASC [7] effectively.

There was 190 white paste beads were found in ossuaries in the Chalcolithic burial cave at Peqi'in, Israel. They have a 2- to 4-millimetre diameter, a 1- to 3-millimetre height, and a 1-millimetre hole. Beads were analysed using x-ray diffraction and SEM (XRD). Silicon, magnesium, and traces of copper and iron are detected in the beads. The beads are made of enstatite, magnesium-containing pyroxene, and cristobalite, a high-temperature polymorph of quartz generated when quartz is heated to 900 to 1470 degrees Celsius. First impressions suggest the beads were made by heating talc. Powdered talc, water, and a binder were mixed to make a paste. The paste was then rolled into thin tubes and heated. Burning made the material more stiff and transformed talc into enstatite and cristobalite. Tubes were then sliced into beads. Israel lacks talc and enstatite. Turkey or Egypt are good sources for these metamorphic rocks. Egypt and the Indus Valley developed similar technology simultaneously. They give the first evidence of Chalcolithic pyro technology being employed for non-metallurgical reasons. The finding is crucial for technological developments and long-distance trade at the time [8].

Sudalaimani and Shanmugasundaram [9] studied how substituting ultra fine natural steatite powder (UFNSP) for cement affects cement setting time and pozzolanic activity. Replacement of ultrafine natural steatite powder with cement at 5%, 10%, 15%, 20%, and 25% by mass was studied. How long are fresh cement-binder paste sets and mortar cubes' compressive strength measured. SEM and XRD were used to investigate the cement-binder matrix's microstructure and chemical element distribution. The data suggest a shorter inactive phase. Ultra-fine natural steatite powder reduces initial and final setting times. Increases the mortar cube's compressive strength.

Using ultrafine natural steatite powder (UFNSP) in place of cement, Kumar et al. [10] tested the flow and compressive strength of self-compacting concrete (SCC).

The results of testing on specimens with 5%, 10%, 15%, 20%, and 25% UFNSP replacement were compared to control specimens. All specimens' flow characteristics were tested and compared to established criteria. After seven, fourteen, twenty-eight, and fifty-six days, each specimen was tested for compressive strength. Microstructural maps of magnesium, calcium, and silicon were produced from hardened materials. Mapping has revealed the existence of M-SH structures. UFNSP reduces flow and boosts compressive strength up to 20% replacement. UFNSP increases microstructure density, which boosts specimen strength.

Sugila Devi and Sudalaimani [11] analyzed calcined magnesite and steatite powder. Magnesite and steatite are milled into a powder at a 3 to 1 weight ratio, and then heated to 1200 degrees Celsius. The calcined powder's microscopic structure, consistency, initial setting time, final setting time, and heat of hydration are tested with and without STPP salt. Using a 0.25 water-to-powder ratio, the powder is converted into a paste, and then the hardened samples are tested for compressive strength, drying shrinkage, pH, SEM, and XRD. Adding phosphate salt to the mixture speeds up hydration, shortens setting time, and increases overall strength. The test samples contained magnesium hydroxide and struvite. According to the study, natural metamorphic steatite and magnesite could be used to make magnesium-based binders. People prefer concrete for its durability. This research used fly ash and ultra-fine natural steatite powder. FA was employed as a cement substitute and UFNSP as an addicting. FA replaces cement in SCC at 10% and 20% by weight. Both replacement levels had 0% to 5%, 10%, 15%, 20%, and 25% UFNSP added dependent on powder weight. Thirteen pairs of specimens were cast and tested for durability, including initial water absorption, saturation water absorption, effective porosity, sorptivity, rapid chloride penetration, and bulk diffusion. Steatite and fly ash serve as fillers in their study. At higher percentages, the same lower voids, which affects effective porosity. SEM pictures support our experiment. Increasing the replacement amount stopped the microcracks, improving the microstructure and reducing voids. SEM images showed the development of magnesium silicate hydrate gels, which contributed to the material's durability [12].

Luukkonen et al. [13] tested if waste soapstone could be used as the major binder in an alkali-activation process using sodium silicate and hydroxide. The findings show that soapstone reacts to some degree (with a compressive strength of 13

MPa after 28 days of ageing), but the mechanical properties are greatly improved when metakaolin replaces 20% of the soapstone (with a compressive strength of 31 MPa after 28 days of ageing). Mechanical properties are similar to virgin soapstone. In terms of high-temperature resistance, acid resistance, freeze-thaw resistance, and sorptivity, alkali-activated binders are comparable to or better than Portland cement-based binders. Alkali-activated soapstone mortar costs about 70 euros per tonne. The findings allow for the environmentally and economically acceptable use of waste soapstone.

The literature study offers the following takeaways, which are highlighted with research gap and problem statements.

The alkali-activated and geopolymer systems require silica and alumina-rich raw feeds that can be activated with sodium or potassium hydroxide and silicates. Silica and alumina affect alkali-activated concrete's durability. Alkali-activated binder needs reactive minerals in the raw feed, which are activated by alkali liquids. Raw materials should be finer and lump-free, along with other chemical criteria. Magnesium-based minerals are good at binding and generate high alkali binding. M-S-H and $Mg(OH)_2$ contribute to magnesium-rich binders' strength, durability, and performance, as does their denser microstructure. Durable and easy to handle, steatite is utilised in refractory and ceramic industries. Even though steatite has fewer reactive compounds, the refractory industry uses it at greater temperatures, which demonstrates reactive compound formation. Ultrafine steatite is used in concrete to improve its strength, durability, and performance. It can also be used to make high-performance self-compacting concrete. Later, steatite is sintered with magnesite and evaluated as a cement alternative. Soapstone, an impure type of steatite, can be activated into a strong alkali binder. This literature review discovered a few remarkable evidences, paving the way for a huge research requirement. Sintered or thermally treated steatite can be utilised as a binding element, especially in alkali-activated concrete. Despite its potential, there is no comprehensive steatite-based alkali activated or geopolymer system.

3. OBJECTIVE

The primary aim/goal of this research is to achieve an alkali activated binder with only UFSP as source materials. Numerous objectives are set and used in this study to accomplish this goal, and those objectives are listed below.

1. To investigate the mechanical strength of fly ash based and slag-based alkali activated concrete, with UFSP as source replacement
2. To investigate the performance and durability of fly ash based and slag-based alkali activated concrete, with UFSP as source replacement
3. To achieve an alkali activated binder through sintered UFSP by effectively varying ratios of Na_2SiO_3/NaOH ratio
4. To investigate the strength and microstructure of sintered UFSP based alkali activated mortar
5. To create an ANN-based predictive model for sintered UFSP based alkali activated mortar

4. RESEARCH PROBLEM AND FINDINGS

Alternative binders and binding technologies are more essential and necessary now than ever since they spread out the use of natural resources rather than focusing and depending on just one. There is a need to find either a pozzolanic additive or an alternate binder since the massive use of cement has put greater strain on the raw material business, which includes limestone and clay. The development of source materials like fly ash, GGBS, and other slags resulted from the successful investigation of the source material for alternative binders over the past few decades. Fly ash supplies are now declining as the globe transitions to sustainability. Natural minerals are found everywhere and can be utilised in enormous supply. Generally speaking, the softer magnesium-based minerals are accessible everywhere. There is a lot of promise for the UFSP, which is being employed in other applications in the building material industry. Recent developments in cement compounds made from magnesium, which often have alkaline and lasting qualities, constitute a significant advance. This study will significantly contribute to the production of alkali activated binders based on magnesium minerals, such as UFSP. This study will also focus on replacing the magnesium-based binder in existing ash- and slag-based alkali activated mortar and concrete to improve their qualities. Concrete with a magnesium-based

binder will be employed in large-scale structural applications that call for simple concrete placement yet high strength, outstanding durability, and environmental friendliness.

As said earlier, this research is based on the single goal of attaining alkali activated concrete and binder with UFSP. For achieving this, there were two paths available, one is gradually replaced UFSP in already available ash based and slag alkali activated concrete and check for its performance. And the second way is treating UFSP and varying activator proportions and investigating the change in alkali activations achieved. For all this, the objectives were set as stipulated in this section. The whole study is framed around the primary goal of achieving UFSP based on alkali activated binder. The entire research is explained in the flow chart given in Figure 1. The full research is divided into two parts; the first part slowly incorporates UFSP into existing conventional alkali activated concrete. And the next is to ideate a process of achieving more reactive UFSP base material through either sintering or altering the ratio of Na_2SiO_3/NaOH in the alkali activators. Finally, the strength of AAC and alkali activated mortar is evaluated, along with the support of other parameters, to give clear evidence of what works and what does not. This study will facilitate future researchers with the idea of using UFSP in alkali activated binding applications.

AAC specimens mixed with UFSP were cast and tested per the guidelines used for regular Portland cement concrete and mortar. Concrete cubes measuring 150 mm x 150 mm x 150 mm had their compressive strength tested in accordance with the guidelines in IS: 516:1959. A split tensile strength test was performed on 150mm diameter and 300mm height cylinders that had been cast and tested in accordance with IS: 5816-1999. For testing the flexural strength of plain concrete, standard AAC beams of 750 x 150 x 150 mm and according to IS: 516-1959, were utilised. According to ASTM C642, durability tests on geopolymer concrete with and without UFSP cubes were carried out, and the outcomes were compared. The structural and tensile behaviour of the geopolymer concrete using thermally treated UFSP as source raw material was further examined. Rapid chloride penetration (RCPT) test, in accordance with ASTM C 1202-94, was used to determine the rate of transport of chloride ions into the concrete in geopolymer concrete with and without UFSP discs of size 90 mm diameter and 35 mm thickness. Additionally, scanning electron

microscopy, energy dispersive X-ray analysis (EDAX), and X-ray diffraction analysis were used to study the microstructure of AAC, and the alkali activated binder.

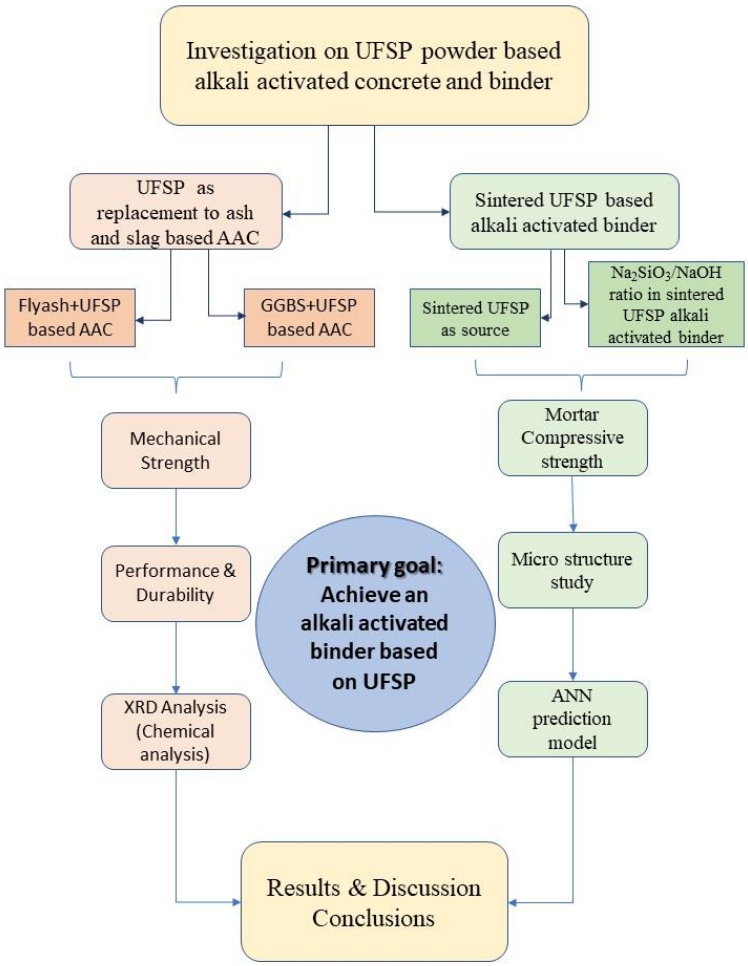
Investigation on UFSP powder based alkali activated concrete and binder
UFSP as replacement to ash and slag based AAC
Sintered UFSP based alkali activated binder
Flyash+UFSP based AAC
GGBS+UFSP based AAC
Sintered UFSP as source
Na_2SiO_3/NaOH ratio in sintered UFSP alkali activated binder
Mechanical Strength
Mortar Compressive strength
Performance & Durability
Primary goal: Achieve an alkali activated binder based on UFSP
Micro structure study
XRD Analysis (Chemical analysis)
ANN prediction model
Results & Discussion Conclusions

Figure 1 Research flow of this study

The result of this study shows that the mechanical strength such as compressive, split tensile and flexural strength were influenced in AAC through the replacement of UFSP. In fly ash-based AAC samples, even 10% of UFSP replacement causes more than 50% strength reduction during early ages. This is due to the lesser activation/resistance towards alkali reaction during the initial ages, offered by UFSP. Contrary to the 7 days result, on 28 days, there was an increment in the strength attainment, and 30% of UFSP replacement provides maximum strength. This compressive strength enhancement is attributed to the denser packing and reaction of alumina and silica in UFSP and fly ash. In fly ash based AAC contrary to

compressive strength, split and flexural strength attainment shows he best value on 50% of UFSP, the strength variation compared to the control specimen is much higher. It shows that UFSP enhances split tensile strength and flexural strength. This behaviour is attributed to the fibrous particle shape of UFSP. In fly ash based AAC the compressive strength reduction occurs with respect to the replacement of UFSP occurs, but not so high. For 10%, 20% of UFSP replacement, the loss in strength is less than 20%. The 28 days strength attainment increases with an increase in UFSP replacement and reaches maximum strength at 30% of UFSP replacement. The GGBS raw feed provides support towards rapid alkali activation and higher enhancement of strength, which reduces the strength alteration due to UFSP. Also, the split tensile and flexural strength results show too higher strength achievement, in GGBS based AAC, due to the particle distribution and shape of UFSP. The fly ash based AAC has lesser correlation between compressive strength to split tensile/flexural strength compared to GGBS based AAC, which is attributed to the interaction of slag particle and UFSP particle.

The rounded fly ash and spikier UFSP particle has lesser interaction when compared to rough slag and UFSP interaction. This in turn concludes that the GGBS based AAC samples show more homogeneity than fly ash based AAC. The 28 days aged samples of fly ash-based show linear reduction in water absorption capacity, with 40% of UFSP replacement posing the least water absorption. After 60% of UFSP replacement, there was a very steep rise in water absorption. This behaviour is due to the additional water requirement or higher water absorption of UFSP, which are naturally available, finer and dry.

The water absorption behavior of GGBS based AAC shows that the addition of UFSP reduces the water absorption till 30% and 40% of UFSP replacement, then after the water absorption raises steadily. The samples of this set of AAC have controlled linear rise in water absorption, and these are due to the performance offered by the slag and its homogeneity

The RCPT results show that GGBS based AAC samples allow more charge passed compared to the fly ash based AAC. The resistance towards the charges given in GGBS is less, which is attributed to the free chloride available in the GGBS based AAC. The fly ash based AAC allows lesser chloride intrusion due to the

discontinuous pores and higher chloride resistance in AAC. When the fly ash and GGBS based AAC samples are exposed to the H_2SO_4 solution, the AAC reacts with sulphate and defoliates the surface. Also, the sulphate exposure affects the AAC homogeneity, causing weight loss and strength loss. The 28 days and 56 days exposure to fly ash based and GGBS based AAC shows similar weight loss in the range of 2% to 3.5%, whereas in 90 days, exposure loss more than 3.5% of the weight. When the UFSP replacement exceeds 60%, there is a heavy loss in weight. The resistance towards strength loss is high in 30% of UFSP replaced samples and very low in higher order UFSP replacement, such as 60% and above. All this behaviour is attributed to the UFSP impact on microstructure and its degradation properties at higher order replacement, but contrary to this, when the replacement is limited to 30% it gives homogeneity and denser microstructure. When the fly ash and GGBS based AAC samples are exposed to the HCl solution, the weight loss and strength loss on 28 days and 56 days is comparatively low than the sulphate exposure, and this is due to lesser chloride penetration, the 90 days loss in strength and weight is almost equal to sulphate exposure.

The performance is best in 20% of UFSP replacements on 28 days and 56 days. On 90 days, the best performance is achieved on 30%, which is attributed to free chlorine available in GGBS based AAC. The XRD pattern of alkali-activated binders based on slag-steatite is displayed in a manner analogous to what is shown in XRD. The appearance of significant peaks at around 30 illustrates the formation of CSH gel in the binders.

The increase in compressive strength of GS30 alkali-activated binders may consequently be attributed to the additional supply of silica, which can be seen as peaks in the figure. This conclusion can be drawn because of the fact that the additional supply of silica can be seen. These effects of adding steatite powder to AAC made from slag and fly ash are under study. The experiment showed that including 20 and 30% steatite powder as an alternate precursor into ambient-cured slag-based specimens results in materials with improved mechanical and durability attributes than the individual slag-based specimens. These results were shown by using steatite powder as an alternative precursor.

Despite this, adding more than 30% steatite powder to slag-steatite concrete affects its performance. All slag-steatite alkali-activated concrete specimens have a lower water absorption rate than control specimens because the powder has a smaller particle size. Using the powder led to this result. The performance of heat-cured fly ash-based specimens was increased by 30% when steatite powder was added. This was compared to fly ash-based samples. The heat drying of the specimens allowed fly ash and steatite to reach more than half of their final strength earlier. When steatite samples are compared to control samples, both FS30 and GS30 have improved durability. The instances can be compared. Therefore, 30% steatite powder replacement in alkali-activated concrete is ideal.

A higher silicate-to-hydroxide ratio may also affect sample strength. Magnesium-based products, which improve strength like calcium-based goods, are to responsible for the strength gain. Past studies show that a ratio of 2.5 sodium silicate to sodium hydroxide maximizes strength increase. Even though soapstone's geopolymer strength isn't as strong as metakaolin's, it's still higher than metakaolin's. Calcined UFNSP could be used in alkali-activated construction materials. Higher silicate to aluminate ratios gives strength, and Mix 7 and Mix 8 with a sodium silicate to sodium hydroxide ratio of 2.5 exhibit the highest silicate to alumina ratio in both groups, which supports the higher performance of the mortar during compression and reflects through greatest strength increase. Alkali activated UFNSP's microstructure is based on Silica, Alumina, and alkali liquid activation. The samples with less silicate activators exhibit unreacted compounds, which is attributed to the lower reaction, while the greater concentration of sodium silicate shows more reaction, comparable to early research, and so the Si to OH ratio is optimal at 2.5. The following observations were made in experimental and prediction studies on alkali-activated UFSP mortar and the effect of transcription factors on strength and microstructure. Na_2SiO_3/NaOH ratio and calcination affect mortar strength. Maximum strength is reached with a silicate-to-hydroxide ratio of 2.5. High-temperature calcination increases strength. All 1000 ^{0}C calcined UFSP-based mortars demonstrate better strength gain compared to 700 ^{0}C UFSP.

This study's strength enhancement is due to reacting magnesium, silicate, aluminium, and denser microstructure. Calcination created more reactive amorphous compounds, which strengthened alkali-activated mortars. Even though the

Na_2SiO_3/NaOH ratio affects strength increase, at a ratio of 3, calcined UFSP loses strength due to a quicker response and weaker microstructure.

The influence of silicate is obvious in the SiO_2/Al_2O_3 ratio in alkali-activated UFSP mortar, and when the ratio reaches 2.5 to 3, the mortar's strength performance is pretty high, supporting the conclusion of Si and Al in mortar strength gain. ANN model performance depends on inputs. Models using EDS, XRD, and basic mix proportion perform better than those with merely mix proportion and SiO_2/Al_2O_3 ratio. Also, a silicate-to-hydroxide ratio of 3 creates large uncorrelation in the model, which lowers its performance. EDS and XRD observations can improve the model's performance. Through experimental and predicted analysis, 1000^0C of calcination temperature and Na_2SiO_3/NaOH ratio of 2.5 is the best steatite-based geopolymer mix for alkali-activated UFSP mortar.

5. ORGANIZATION OF THESIS

The seven chapters that comprise the thesis' main body are followed by an appendix containing detailed data and computations for the mix design. The seven chapters of the thesis are included here, with a brief summary of each. A concise summary of the entire thesis is presented in Chapter 1's introduction, which also provides a general overview of steatite, geopolymerization, and alkali activation. It also talks about how both are applied. In-depth reviews of earlier studies that are connected to the topic of the current investigations are provided in Chapter 2. Studies on AAC/GC, studies on magnesium-based cement and concrete technology, and studies on steatite are some of the topics covered in this chapter. At the conclusion of this thesis, references to pertinent material are included separately under the heading "References." The purpose and goals of the study and the many stages of the work involved are described in Chapter 3. The physical and chemical characteristics of the materials utilised in this study are discussed in Chapter 4, together with the mix proportions estimated for self-compacting concrete. The formulation of mixes for UFSP-based alkali activation concrete is discussed in Chapter 5, along with an analysis of the durability response of AAC specimens and an alkali activated binding system. The description, analyses, and discussion of the data acquired from the experimental study are presented in Chapter 6, Results and Discussion. This chapter also offers the analytical model created utilising the experiment's results. The

investigation's findings are summarised in Chapter 7's conclusions and scope for further work, which also offers suggestions that could be implemented to strengthen the findings so far.

6. BREIF CONCLUSIONS

The entire body of work done in this research project aims to comprehend, assess, and implement the method of producing UFSP for use as the source material in the alkali activated binding process. The entire study is structured in such a manner that two categories of studies are designed to examine the practicability of using UFSP as a source material in alkali activation. These studies are designed to determine whether or not the use of UFSP is possible. The first step involves gradually substituting UFSP for fly ash and slag in the manufacturing process of alkali-activated concrete (AAC). These two materials are traditionally used as raw feed for AAC. The second step involves incorporating the sintered UFSP into an alkali activated binder in a raw feed capacity. All of these studies are supported by a large number of experiments, and the findings of those experiments have already been reviewed. These findings provide us with a perspective and some conclusions, both of which are going to be utilised in the ongoing process of developing this work.

- The overall observation shows that Fly ash based AAC and GGBS based AAC can be manufactured with UFSP replacement, up to a limit of 30% for better performance on all aspects, but the possibility of using UFSP as raw feed in AAC is completely not possible, as these samples are having mostly inferior performance in comparison to all other samples.
- Even though achieving raw UFSP in alkali activation is impossible, the thermally treated UFSP is also studied with various proportions of silicate to hydroxide ratio. The study concludes that higher temperature(1000^0C) and ratio of silicate to hydroxide at 2.5 gives the best value on performance. Also, this study can be converted into a predictive model in ANN showing results of best fit, ensuring the future prediction of sintered UFSP as source materials for alkali activated binder.

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LIST OF PUBLICATIONS

1. **R. Premkumar**, C. Ramesh Babu, M. Shanmugasundaram and PL. Meyyappan, A study on influence of Na_2SiO_3/NaOH ratio on calcined magnesium silicate based geopolymer - Experimental and predictive study, *Journal of Wuhan University of Technology – Materials science Edition* (Impact factor 3.426 - ACCEPTED)
2. **R. Premkumar,** C. Ramesh Babu, VS. Athira, A. Bahurudeen and M. Shanmugasundaram, Influence of ultrafine steatite powder on the mechanical and durability properties of alkali-activated concrete, *Proceedings of The Institution of Civil Engineers-Engineering Sustainability* **1**(2022), 1-11
3. **R. Premkumar**, C. Ramesh Babu, M. Shanmugasundaram and A. Ragasree, Study on mechanical properties of alkali activated binary blended binder containing steatite powder and fly ash / GGBS, *IOP Conference Series: Materials Science and Engineering*, **872** (2020) 012153
4. **R. Premkumar**, C. Ramesh Babu and M. Shanmugasundaram, Durability Performance of Fly Ash and Steatite Powder Based Geopolymer Concrete, *IOP Conference Series: Materials Science and Engineering*, **561** (2019), 012055